October 30, 2016

Betsy Steiner
EPS Industry Alliance
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Re: Project No. 10424
Review of UL Study of Residential Attic Fire Mitigation Tactics and Exterior Fire Spread Hazards on Fire Fighter Safety

Dear Ms. Steiner:

The purpose of this project is to review the UL fire mitigation study referenced above and provide feedback based on our findings of the review.

Background

EPS insulation has a long history of code compliant applications – including code prescribed fire test approvals. Listed/certified EPS complies with flame spread criteria (ASTM E84/UL 723), exterior wall criteria (NFPA 285), and room corner fire test criteria (UL 1715, NFPA 286) when used in specific configurations. The array of approved assemblies is too long to list in this report but many of these approvals are found in various approval agency certification programs such as UL, ICC-ES, Intertek (OPL, WH), SWRI, IAPMO, and many other certification agencies.

Behavior of EPS Directly Exposed to Flames

EPS insulation has a unique property which "protects" itself from ignition in specific scenarios. When exposed to a flame (or heat), EPS melts very quickly. Under close observation, the heat flux from a flame appears to "push back" the EPS surface as the surface melts. If one moves the flame closer, the EPS surface "backs away" from the flame source due to additional melting. In a sense, EPS removes itself from flame sources in some conditions. This process is what happens when one tests thin, low density EPS in room corner fire tests.

Most room burn test standards (e.g., UL 1715, NFPA 286, etc.) use a standardized 8 ft x 12 ft x 8 ft high room lined on the interior with the material being evaluated. The acceptance criteria for each test varies but in all cases, a more flammable material will end in results approaching the limits of the criteria.

Note: It is interesting that the listed values for Steiner Tunnel tests of EPS use special criteria (See UL 723). The FSI/SDI numbers used for certification are the values obtained up until molten EPS starts burning on the floor. The reason for this is because this way of interpreting results correlates with how EPS behaves in room corner fire tests.

In the discussion below, a detailed analysis is described (based on actual experience) for thin applications of low density EPS foam in room corner fire tests. We may regard thin as being approximately 1 to 1.5 inches and low density as 1 to 1.5 pcf.

Thin Low Density EPS in Room Corner Fire Tests

In a room corner fire test of EPS, the flames from the burner typically melt the EPS quickly. If the foam is thin, the flames may never really ignite the surface of the foam. In some cases, as the foam melts and drips in the test corner, ignition sometimes occurs on the molten material attached to the wall. The amount of EPS melted to the wall surface is small and is difficult to ignite in these applications. If ignition occurs, the wall flame is short lived and does not readily spread flames upward or laterally. In these cases, the measured net heat release rate (gross HRR minus burner HRR), is very near zero.

Thick/Dense EPS can behave differently.

EIFS Applications
In EIFS exterior wall constructions, the system must comply with NFPA 285. An EIFS wall is simply a base wall (interior gypsum board, studs, exterior gypsum board) with EIFS applied over the wall. The EIFS layers (over the base wall) can consist of EPS insulation, base coat, mesh, and finish coat. The EIFS coatings (base coat, mesh, finish coat) are typically around ⅛ inch. The following explains why many of these assemblies pass the test.

In the NFPA 285 test, the EPS melts to the surface of the gypsum wallboard (for the reasons as stated for room corner fire tests above). However, flame spread does not occur within the cavity left behind because the environment is fuel rich with little or no air available for combustion. In fact, the system pressurizes with foam vapors which are expelled outward through the EIFS layers (Base coat/Mesh/Finish Coat). It is only these expelled vapors which can ignite on the exterior of the wall surface. The EIFS coatings (Base Coat, Mesh & Finish Coat) are very durable under NFPA 285 fire conditions and prevent the foam core from spreading uncontrolled flames – hence the NFPA 285 compliance of these systems.

Discussion of Scenarios Listed Above
Clearly, EPS can pass very severe fire tests due to the unique nature of how EPS behaves when exposed to flames or heat. So, the question is, Why did the walls in the UL study as referenced herein burn in the manner as described in their published data?

Analysis of the UL Study
The general overview section discusses this as a research project on wall flammability comparisons to determine the worst case - which causes attic fires that transition from exterior fires. The main purpose of the study was to focus on attic fires. But the general overview focuses on wall flammability as a source for attic fires.

As quoted in the UL Document,

"The research proposed herein is not to critique modern construction products and practices that assist in reducing our energy footprint but to understand the impact of these decisions on the dynamics (i.e., fire initiation, growth, spread, etc.) of fires originating either in the attic or on the home exterior and the hazards to firefighters on the scene."

The paper slowly transitions to wall fires being a concern. The paper then transitions to concerns using “green initiative” products (foam insulation) which improve insulation of the home. The paper then transitions to exterior fires causing attic fires. Next, the paper starts discussing the use of foam insulation with vinyl siding as a common building practice, and blames energy conservation goals (high R values) as the culprit in the use of foam insulation in stud cavities and rigid foam as a sheathing.

The document states:

"Over the last eight years the International Energy Conservation Code (IECC) for single family residential structures has changed significantly, requiring more thermal resistance. This increase in thermal resistance has changed the construction of wall assemblies inadvertently changing the fire hazard of exterior walls."

The paper goes on to state that the most direct way to meet energy codes is to use polystyrene insulation as a sheathing.

The document states:

"The most commonly used sheathing material with an R-5 insulation rating is 1 in. rigid polystyrene foam insulation board which behaves much differently than the conventional plywood sheathing during fire exposure." and,

"Over the last three code cycles, 2006-2012, there has been a trend of increasing R-Values required in exterior wall construction. Table 1. 1 shows that for the 2006 code R-13 was required for the majority of the climate zones which by 2012 has been increased to R-20. The most significant increase occurred in 2012 where the insulation value in zones 3 and 4 went from R-13 to R-20. This change mandated that new home construction in over 90% of the US must achieve or exceed an R-20 wall thermal resistance value. Options are provided to achieve this, builders may also opt to utilize an R-13 insulation with an R-5 sheathing or utilize the cavity insulation alone to achieve the R-20 value." This leaves builders few options other than foam plastic insulations."

Soffits

On page 21, the peer states that the soffit materials remained constant – but does not state of what material they were made. On page 244 is the first instance where the soffit material was vinyl. On page 257, it is mentioned that wood based soffits have been replaced by vinyl soffits in recent years. On the same page the paper states:

"Fires adjacent to modern exterior wall construction have the potential to transition to structure fires within two minutes of ignition."

On page 259, the paper states:

"As a result, when spray foam is used, there is usually a return to solid eaves and soffits which resist the spread of fire into the attic space."

On page 281, the paper states:

"A current code proposal exists for the North Carolina Residential code which would require "protected soffits". These soffits would be required on "buildings with less than a 10 feet fire separation distance". Protection is provided by attaching "fire retardant treated wood, 23/32 inch wood sheathing or 5/8 inch exterior grade moisture resistant gypsum board" under the vinyl or aluminum soffits. Further research is required to effectively quantify the potential for an exterior fire to enter the attic space specifically with the construction practices listed above."

These statements in the UL report confirm our statement above. In fact, solving the soffit issue could solve the main problem of exterior fires entering living spaces through soffits/eaves and engaging the attic. It seems that a major improvement of the fire behavior would result from the use of more robust soffits – especially with high R value demands which requires modern insulation materials. The best case would be to require soffits and attic vent screens to be of very limited combustibility (as required in the IBC Section 504).

On page 262, the paper states:

> **Exterior wall fires may easily spread to the interior at locations other than the eaves and soffits.** The spread of fire from the exterior of the structure through the wall to the interior living spaces is limited by the fire barrier provided by the gypsum wall board on the inside face of the wall. The fire resistive nature of gypsum wall board protects the interior contents and occupants of the structure during an exterior wall system fire by limiting the temperature rise on the interior side of the wall and stopping the migration of fire gases into the living space. **Any penetrations -- such as air vents, electrical receptacles, plumbing penetrations to faucets and drains, and especially windows -- provide the opportunity for fire spread into the interior of the structure.**

This problem can be solved by requiring modern penetration fire-stops that comply with ASTM E814 for thru-penetrating items. However, these residential walls are not code-required to be fire resistant.

Preliminary Observations of Test Results

In this side view of the medium scale test #4, the edges of the wall are not sealed. This setup allows air to easily flow through the system and affect test results. In real constructions, the air availability in the wall is limited by the perimeter length of the structure. In exterior wall fire tests (NFPA 285), wall edges are sealed.

Table 6. 11: Wall Type and Material for Experiment 4 (150 kW)

Wall Type	Siding	Additional Material	Sheathing	Insulation	Back Wall
Wall 8	Double 4" Vinyl Siding	Weather-Resistant Barrier	1" R-5 EPS Insulation Board	2x6, R-19 KFI w/ IVB	1/2" Gypsum Board

Figure 6. 11: Wall Type 8 Side View

Test # 1, 2, 3 of the eaves tests show similar edge details (not sealed).

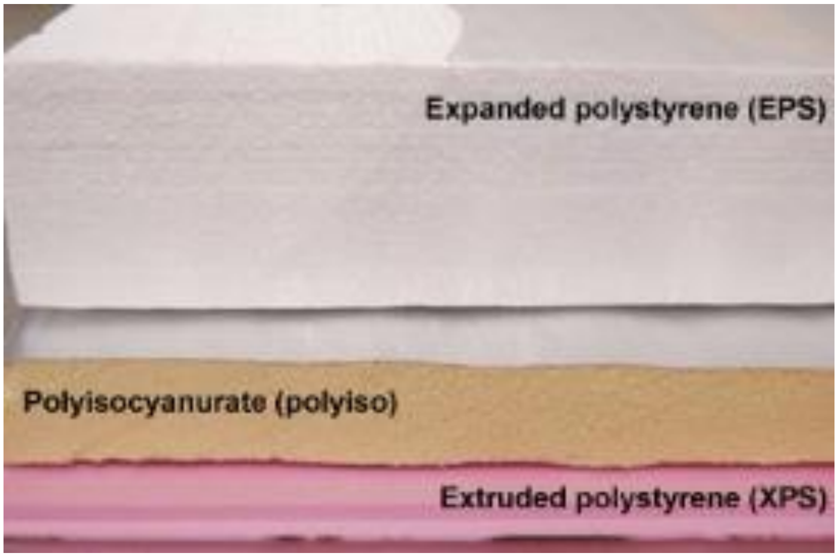
Figure 7. 5: Rear View of Eave Structure for Experiment 2

Insulation Type Analysis
Upon review of the UL study, one item seemed to prevail – the misuse of terminology describing the products tested. The term polystyrene, and EPS were used throughout, but there was no mention of extruded polystyrene or XPS as it is commonly referred to. It is our contention that EPS insulation was not used in any of the UL experiments. Below are excerpts from the report and our commentary.

In test #4, the insulation is listed as EPS (Expanded Polystyrene). Clearly this is incorrect as the board is pink extruded polystyrene (XPS) by a well-known manufacturer of XPS.

Figure 6. 11: Wall Type 8 Side View

Experiment #4 (page 43), 5 (page 47), 6 (page 51), 8 (page 58), 9 (page 62), 11 (page 68), 12 (page 72), 13 (page 76), 14 (page 79), 15 (page 82), 18 (page 91), 19 (page 95), 20 (page 99), 21 (page 103), 24 (page 112), 26 (page 118) all show the same pink colored XPS – not the white EPS which has a bead like structure as shown below:



Difference between XPS and EPS

The fire behavior of EPS and XPS can be different since each industry uses variations of fire retardant loadings and polystyrene raw materials. Any results attributed to EPS are questionable since the insulation tested was actually XPS. EPS is formed by expanding beads of polystyrene within a form. The density is controlled by the volume of the form during the expansion process. XPS is produced by melting polystyrene crystals and extruding the product into a closed cell structure and expanded into various densities during the cooling process. Fire retardant additives are blended in to improve the ignition and burning properties of the final product (compared to non-FR treated). The details of how the additive is used (i.e., during forming or from the raw product used to make the final product) is proprietary.

The following is from Owens Corning (Ref. Owens Corning publication 10018681-A):

Polystyrene Insulation Types

There are two types of rigid polystyrene foam plastic insulation, extruded (XPS), and expanded (EPS).

- XPS is manufactured in a continuous extrusion process that produces a homogeneous closed cell cross section (Fig 1).
- EPS is manufactured by expanding spherical beads in a mold, using heat and pressure to fuse the beads together where they touch, leaving open spaces between the beads where they don't touch (Fig. 2).

Although both types are comprised of polystyrene, the two types of manufacturing processes produce finished products with very different performance properties. Of the two types, EPS absorbs more water in laboratory tests and in application resulting in reduced performance. This bulletin explains the important difference between XPS and EPS and demonstrates that extrusion matters.

Figure 1: Extruded Polystyrene Cell Structure

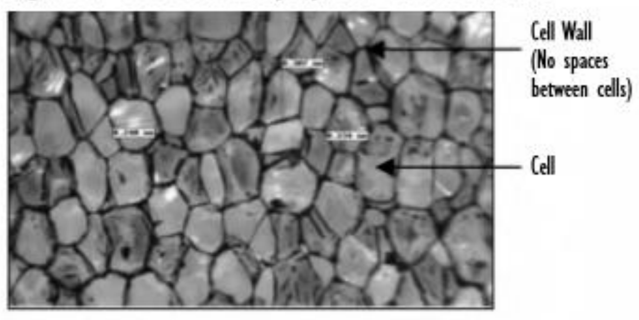
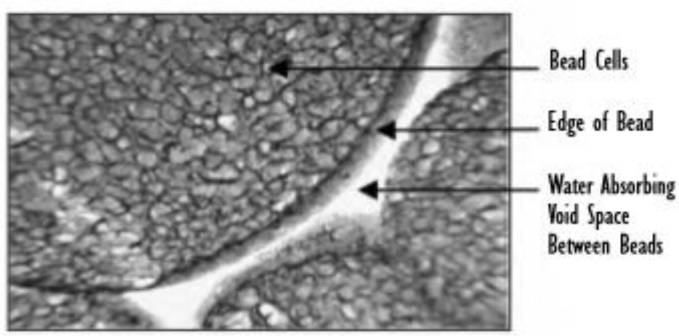


Figure 2: Expanded Polystyrene Cell Structure



The following information is from the EPSIA Home Page: http://epsindustry.org/building-construction/fire-resistance

Under certain fire conditions, EPS will ignite when exposed to an open flame. The transfer ignition temperature is typically 680°F (360°C).

According to the Owens Corning MSDS for Foamular, the flash point of XPS is > 615°F. According to the Dow Styrofoam MSDS, the flash point (auto-ignition temperature is 669°F. Both of these are lower than the temperature cited by EPSIA above.

Clearly, XPS is different than EPS. If the water absorption issue is true, EPS could be more difficult to ignite than XPS under normal use after aging.

From all of the information cited above, results on XPS in the UL report cannot be assigned to EPS.

Thickness Analysis

The thickness stated for many tests do not seem correct. Most list 1" EPS thickness but photographic comparison indicates an inconsistency in thickness when compared to the stud size or when compared to the ½ inch gypsum board or plywood sheathing.

Experiment #4 lists 1 inch EPS as depicted below. The thickness seems correct compared to the ½ inch gypsum wallboard.

Table 6. 11: Wall Type and Material for Experiment 4 (150 kW)

Wall Type	Siding	Additional Material	Sheathing	Insulation	Back Wall
Wall 8	Double 4" Vinyl Siding	Weather-Resistant Barrier	1" R-5 EPS Insulation Board	2x6, R-19 KFI w/ IVB	1/2" Gypsum Board

Experiment # 9 lists the same thickness but the photo shows it to be more like ½ inch (note yellow SPF insulation seeping out between stud and XPS).

Table 6. 26: Wall Type and Material for Experiment 9 (100 kW)

Wall Type	Siding	Additional Material	Sheathing	Insulation	Back Wall
Wall 9-C	Double 4" Vinyl Siding	Weather-Resistant Barrier	1" R-5 EPS Insulation Board	2x6, Closed Cell Foam	1/2" Gypsum Board

Experiment #11 (below) lists 1 inch EPS with ½ inch plywood. Clearly, the insulation thickness is closer to ½ inch than 1 inch – especially when compared to the ½ inch gypsum board.

Experiment # 14 lists ½ inch EPS. Note the similarity in thickness to the ½ inch gypsum board.

Table 6. 41: Wall Type and Material for Experiment 14 (100 kW)

Wall Type	Siding	Additional Material	Sheathing	Insulation	Back Wall
Wall 11	8" Wood Lap Siding	Weather-Resistant Barrier	1/2" EPS Insulation Board	2x6, Spray Polyurethane Foam	1/2" Gypsum Board

Wall Test Results Analysis

The following is an analysis of the medium scale wall tests as outlined in the UL report.

Test #1 (vinyl w/ plywood, fiberglass, 150 kW burner) reached 7 ft in 1:54
Test #4 (vinyl, XPS, fiberglass 150 kW burner) reached 7 ft in 1:06

In the tests above, the difference in times to reach 7 ft is insignificant. (less than 1 minute)

Test #3 (vinyl w/ plywood, fiberglass, 100 kW burner) reached 7 ft in 2:25

Test #5 (vinyl, XPS, fiberglass 100 kW burner) reached 7 ft in 1:19
Test #8 (vinyl, XPS, OC SPF 100 kW burner) reached 7 ft in 0:55
Test #9 (vinyl, XPS, CC SPF 100 kW burner) reached 7 ft in 1:14

In the tests above, the difference in times to reach 7 ft is insignificant.

The time for flames to reach the tops of the walls for a large majority of the tests with vinyl siding (regardless of the insulation or sheathing used in the tests) is 1 to approximately 2 minutes. The UL report puts more significance in the peak HRR in these results, but in reality, from a fire hazard point of view, all of these assemblies using vinyl siding spread flames faster than the typical firefighter response.

It is only when the walls are clad with more robust materials (Test 14, 17, 19, 25 - 28) that the time for flames to reach the top of the wall starts approaching typical firefighter response times (see below).

"Regardless of region, season, or time of day, structure fire response times are generally less than 5 minutes [50%] of the time. The nationwide 90th percentile response time to structure fires is less than 11 minutes." Source – FEMA http://www.usfa.fema.gov/downloads/pdf/statistics/v5i7.pdf

Eave Experiment Analysis

In the eave experiments, test #1 had no EPS insulation. However, test #2 and #3 both list 1 inch EPS as the exterior insulation.

Table 7. 1: Wall Type and Material for Experiment 1

Wall Type	Siding	Additional Material	Sheathing	Insulation	Back Wall
Wall 1	Double 4" Vinyl Siding	Weather-Resistant Barrier	1/2" Plywood Sheathing	2x4, R-13 KFI w/ IVB	1/2" Gypsum Board

Table 7. 4: Wall Type and Material for Eave Experiment 2

Wall Type	Siding	Additional Material	Sheathing	Insulation	Back Wall
Wall 8	Double 4" Vinyl Siding	Weather-Resistant Barrier	1" R-5 EPS Insulation Board	2x6, R-19 KFI w/ IVB	1/2" Gypsum Board

Table 7. 7: Wall Type and Material for Eave Experiment 3

Wall Type	Siding	Additional Material	Sheathing	Insulation	Back Wall
Wall 9	Double 4" Vinyl Siding	Weather-Resistant Barrier	1" R-5 EPS Insulation Board	2x6, Spray Polyurethane Foam	1/2" Gypsum Board

Based on the observations of the misuse of the term EPS in the medium scale tests (#1-28), it is doubtful that the insulation was actually EPS. The photographs are not clear enough to distinguish the exterior insulation color as shown below:

Figure 7. 5: Rear View of Eave Structure for Experiment 2

Conclusion

It is our contention that all references to polystyrene or EPS were actually pink extruded polystyrene (XPS). Any results attributed to EPS cannot be made as equivalent to the actual insulation tested – namely XPS. The following bullet points outline our findings.

1) In the tests, wall edges were not sealed. This allows air to enter an otherwise air limited region of the wall in real constructions
2) The EPS or polystyrene insulation reported is not EPS (Expanded Polystyrene).
3) The polystyrene tested is pink XPS (Extruded Polystyrene).
4) EPS is different that XPS. To what degree and what effect that may have on these results have not been determined.
5) Some of the insulation thicknesses reported seem incorrect.
6) In the medium scale tests, the time for flames to reach the tops of the walls for a large majority of the tests with vinyl siding (regardless of the insulation or sheathing used in the tests) is 1 to approximately 2 minutes.
7) Firefighter typical response times are in the 5 minute range.
8) The statements in the UL report concerning soffits and eaves confirms our statement that the soffit material is the real issue here – especially with high R-value demands which require use of modern insulation products.
9) The UL report indicates that interior fires caused by exterior fires can enter through wall openings required for plumbing, electricity, vents, etc. This problem can be solved by requiring modern penetration fire-stops that comply with ASTM E814 for thru-penetrating items.

Submitted by,

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Reviewed and Approved,

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President

October 30, 2016

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